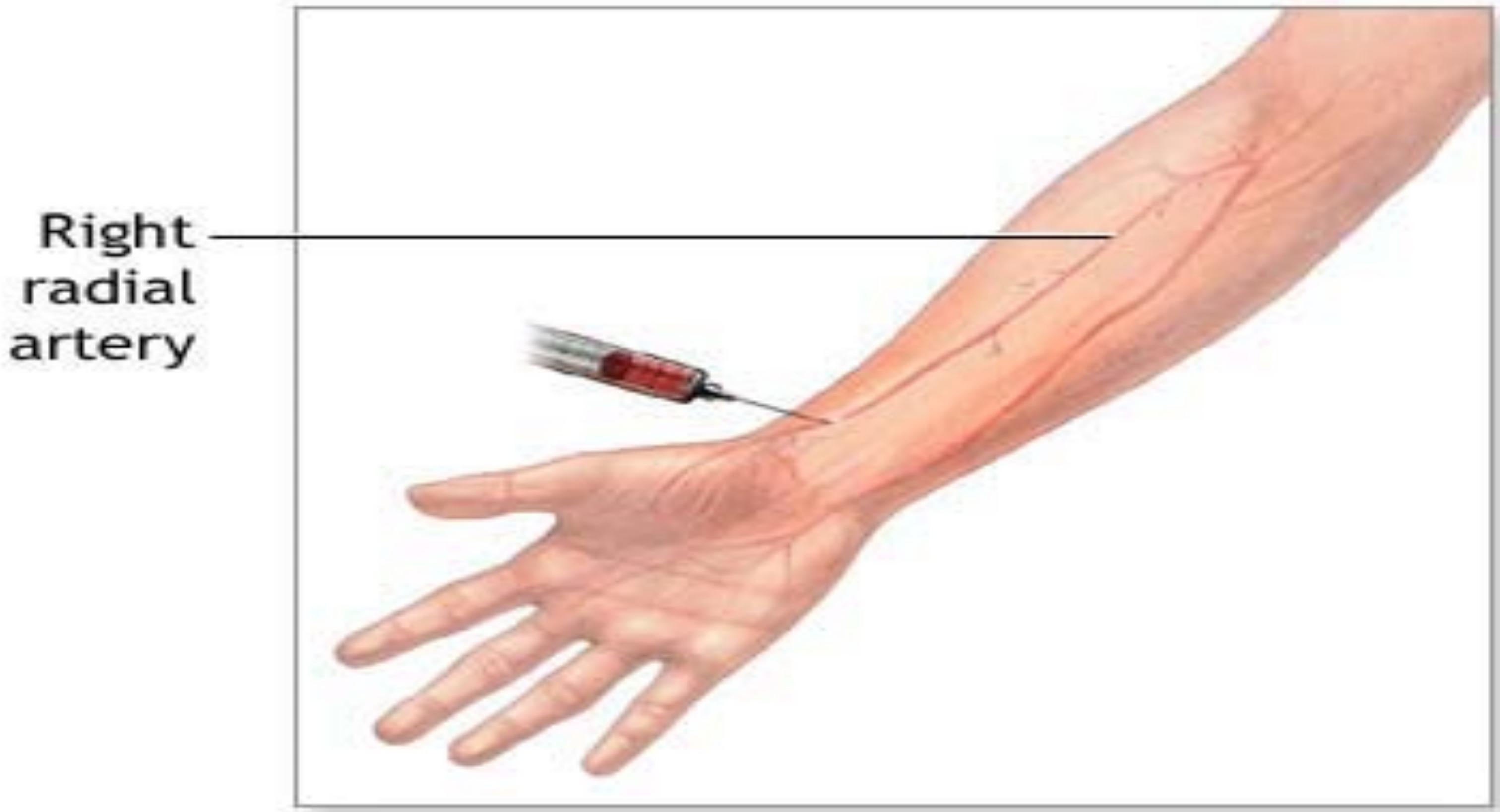
# Interpretation of Blood Gases

Chapter 7

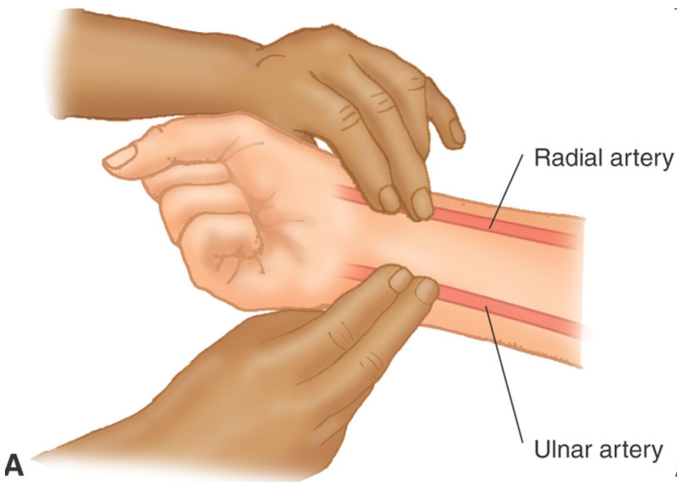
Precise measurement of the acid-base balance of the lungs' ability to oxygenate the blood and remove excess carbon dioxide



# Arterial Blood Sampling

- Analyzing arterial blood samples is an important part of diagnosing and treating patients with respiratory failure
- The radial artery is most often used because:
  - It is near the surface and easy to stabilize
  - Collateral circulation usually exists (confirmed with the modified Allen's test)
  - No large veins are near
  - Radial puncture is relatively pain free

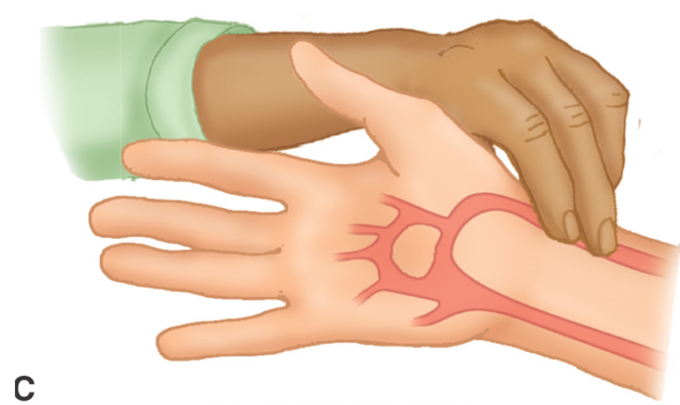
# Modified Allen's test



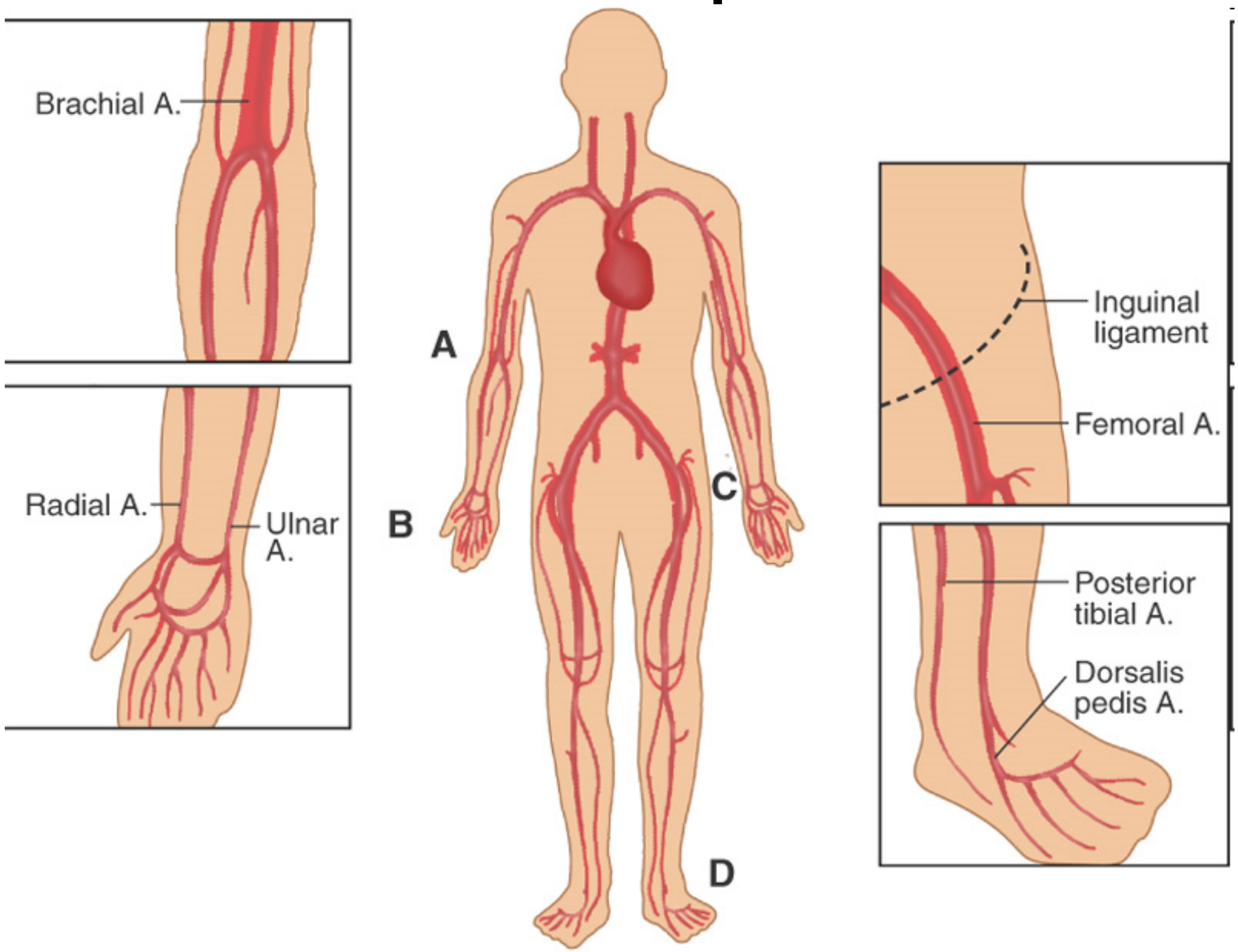




Assessment of collateral circulation before radial artery sampling. **A,** Patient clenches fist while examiner obstructs radial and ulnar arteries. **B,** Patient gently opens hand while pressure is maintained over both arteries. **C,** Pressure over ulnar artery is released, and changes in color of patient's palm are noted. (From Wilkins RL, Stoller JK, Scanlan CL: *Egan's fundamentals of respiratory care*, ed 8, St Louis, 2003, Mosby.)



# Sites of arterial punctures



# ABG Processing

- Obtain sample without exposure to the environment
- Air bubbles should be removed
- Store sample on ice to inhibit metabolism
- Proper care of the puncture site
- Analyzed within 1 hour with properly calibrated and maintained equipment

# Indications

- Acute shortness of breath/tachypnea
- Chest pain
- Hemoptysis
- Cough, fever and sputum production consistent with pneumonia
- Headache
- Past medical history
- Abnormal breath sounds
- Cyanosis
- Heavy use of accessory muscles
- Unexplained confusion
- Evidence of chest trauma
- Severe electrolyte abnormalities
- Changes in ventilator settings
- CPR
- Abnormal chest radiograph

# ABG's Evaluate

- Acid-Base Balance
  - pH, $PaCO_2$, $HCO3^-$, BE
- Oxygenation Status
  - $PaO_2$, $SaO_2$, $CaO_2$, $PvO_2$
- Adequacy of ventilation
  - $PaCO_2$

# Assessment of Oxygenation

- Measurements must be evaluated to identify the quantity of oxygen transported in the blood
- Tissue oxygenation status must be determined

# Oxygen

In the blood:

- Oxygen bound to hemoglobin: **$SaO_2$**
- Dissolved gas in the plasma: **$PaO_2$**
- Total content of oxygen in the arterial blood: **$CaO_2$**

# $P_aO_2$

- normal values: 75-95mmHg
- Reflects the ability of the lungs to allow the transfer of oxygen from the environment to the circulating blood
- Normal predicted values depends on:
  - Barometric pressure
  - Patient's age
  - $FiO_2$

# Alveolar air equation

$$P_AO_2 = F_iO_2\,(P_B - P_{H_2O}) - (P_aCO_2 \times 1.25)$$

$$P_iO_2 = F_iO_2\,(P_B - P_{H_2O})$$

# HYPOXEMIA ≠ HYPOXIA

- HYPOXEMIA
- HYPOXIA

# Hypoxemia

## $P_aO_2$

- 80-100 mmHg = normal
- 60-79 mmHg = mild hypoxemia
- 40-59 mmHg = moderate hypoxemia
- <40 mmHg = severe hypoxemia

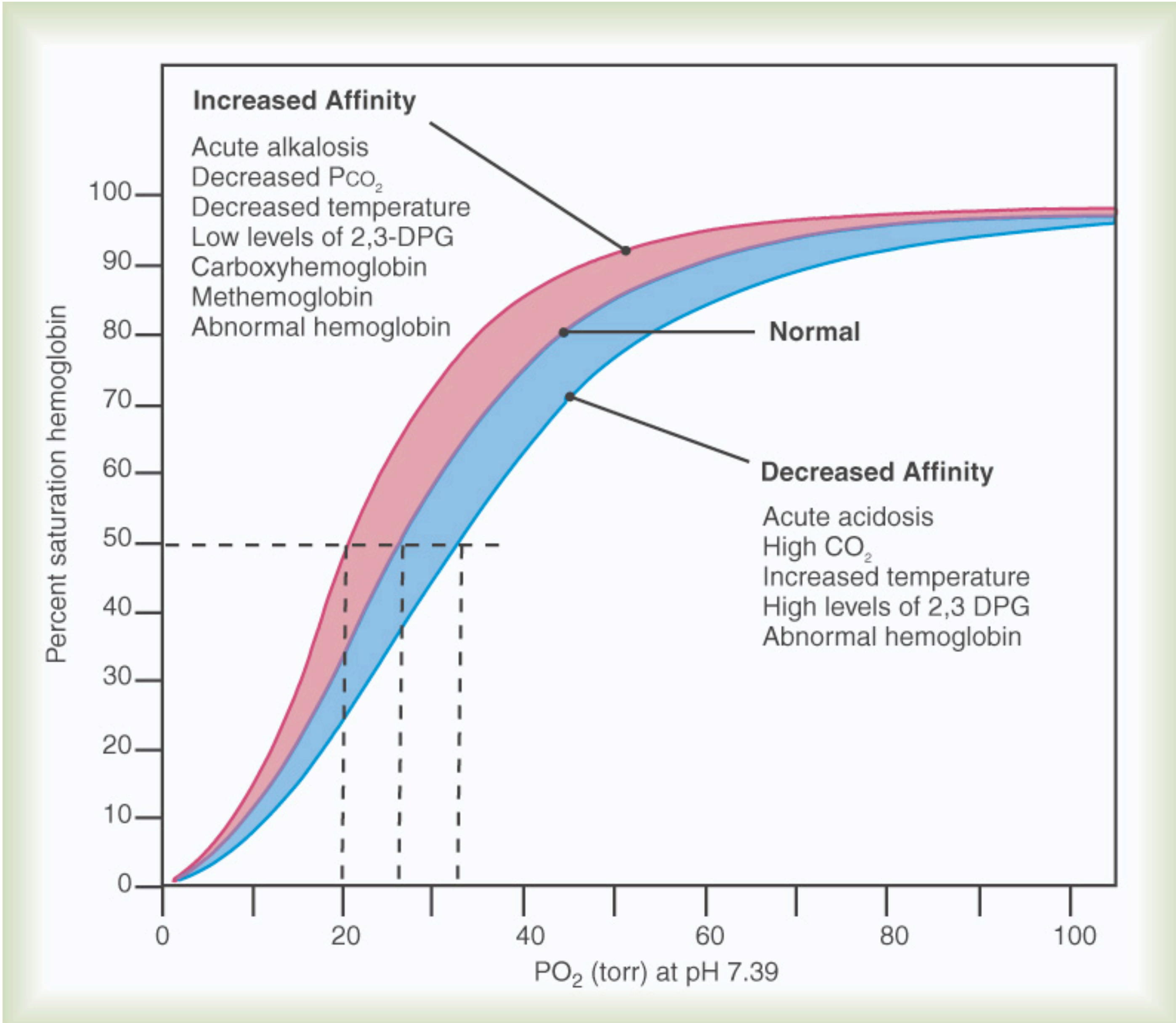
## Causes

- V/Q mismatch
  - Mucus plugging
  - Bronchospasm
- Diffusion defects
- Hypoventilation
- Low $P_iO_2$

# $S_aO_2$

- normal = 95-100%
- Index of the actual amount of oxygen bound to hemoglobin
- Determined from a co-oximeter

- Body temperature
- Arterial pH
- $P_aCO_2$
- Abnormal Hb




(Modified from Lane EE, Walker JF: Clinical arterial blood gas analysis, St Louis, 1987, Mosby.)

# $C_aO_2$

- normal = 16-20 vol%
- Significantly influences tissue oxygenation
- $(1.34 \times Hb \times S_aO_2) + (P_aO_2 \times 0.003)$
- Reductions due to:
  - Anemia
  - Abnormal Hb

# $P_{A\text{-}a}O_2$

- Normal = 10-15 mmHg on Room Air
- Pressure difference between the alveoli and arterial blood
- Predicted normal depends on
  - Age
  - $F_iO_2$
- Estimate for patients on room air =

  age x 0.4

- Increased gradient = respiratory defects in oxygenation ability
- Hypoxemia with a normal A-a gradient
  - Primary hyperventilation
  - High altitudes

# $P_vO_2$

- Normal value 38-42 mmHg
- Indicates tissue oxygenation
- Only obtained through pulmonary artery sampling
- Value <35mmHg indicates that tissue oxygenation is less than optimal

# $C_{(a-v)}O_2$

- Arterio-venous oxygen difference
- Normal value 3.5-5vol%
- Increase = perfusion of the body organs is decreasing
- Decrease = tissue utilization of oxygen is impaired

# Acid-Base Balance

- Lungs and kidneys excrete the metabolic acids produced in the body
- Breakdown of this process leads to acid-base disorders

# pH

- 7.35-7.45
- Reflects the acid-base status of the arterial blood
- Majority of body functions occur optimally at 7.40, deviation from this have a profound effect on the body

# $P_aCO_2$

- 35-45 mmHg
- Reflects the respiratory component of the acid-base status
- Hypercapnia
  - hypoventilation
- Hypocapnia
  - hyperventilation
- Best parameter for monitoring the adequacy of ventilation

# $HCO_3^-$

- 22-26mEq/L
- Metabolic component of the acid-base balance
- Regulated by the renal system
- Compensatory response for changes in $P_aCO_2$

# Base Excess

- ± 2 mEq/L
- Reflects the non-respiratory portion of acid-base balance
- Provides a more complete analysis of the metabolic buffering capabilities
- + value: base added or acid removed
- - value or base deficit: acid added or base removed

# Hendersen-Hasselbalch

$$pH = pK + \log \frac{HCO_3^-}{P_aCO_2 \times 0.03}$$

pK = 6.1

Defines the effects of $HCO_3^-$ and $P_aCO_2$ on the acid-base balance

# Acid-Base Disturbances

- Normal Acid-Base Balance
  - Kidneys maintain $HCO_3^-$ of ~ 24mEq/L
  - Lungs maintain $CO_2$ of ~ 40mmHg
  - Using the H-H equation produces a pH of 7.40
- Ratio of $HCO_3^-$ to dissolved $CO_2$= 20:1
  - Increased ratio = alkalemia
  - Decreased ratio = acidemia

# Clinical Recognition of Acid-Base disorders

**Respiratory Acidosis**

- Reduction in alveolar ventilation relative to the rate of carbon dioxide production
- Inadequate ventilation
- Compensated as kidneys retain $HCO_3^-$

**Respiratory Alkalosis**

- Increase in alveolar ventilation relative to the rate of carbon dioxide production
- Hyperventilation from an increased stimulus or drive to breathe
- Compensated as kidneys excrete $HCO_3^-$

# Clinical Recognition of Acid-Base disorders

**Metabolic Acidosis**

- Plasma $HCO_3^-$ or base excess falls below normal; buffers are not produced in sufficient quantities or they are lost
- Respiratory response = Kussmauls respiration

**Metabolic Alkalosis**

- Elevation of the plasma $HCO_3^-$ or an abnormal amount of H+ is lost from the plasma
- Tends to remain uncompensated since patient would have to hypoventilate

# Compensation for Acid-Base Disorders

- Compensation occurs within the limitations of the respiratory or renal systems
- pH 7.38; $P_aCO_2$=85mmHg with an elevated plasma $HCO_3^-$

# Mixed Acid-Base Disorders

**Respiratory and Metabolic Acidosis**

- Elevated $P_aCO_2$ and reduction in $HCO_3^-$ Synergistic reduction in pH
- Occurs in:
  - CPR
  - COPD and hypoxia
  - Poisoning, drug overdose

**Respiratory and Metabolic Alkalosis**

- Elevated plasma $HCO_3^-$ and a low $P_aCO_2$
- Occurs due to
  - Complication of critical care
  - Ventilator induced

# Acid-Base Assessment
# Oxygenation Assessment

# Capillary Blood Gases

- Often used in infants and small children
- A good capillary sample can provide a rough estimate of arterial pH and $PCO_2$
- The capillary $PO_2$ is of no value in estimating arterial oxygenation
- The most common technical errors in capillary sampling are inadequate warming and squeezing of the puncture site

# Blood Gas Analyzers

- Accurate measurements of pH, $PCO_2$, $PO_2$
- Electrodes
  - Sanz electrodes
  - Severinghaus electrodes
  - Clark electrodes
- Point of Care analyzers (POC)

# Quality Assurance

- Accurate ABG results depend on rigorous quality control efforts.
  - The components of quality control are
  - Record keeping (policies and procedures)
  - Performance validation (testing a new instrument)
  - Preventative maintenance and function checks
  - Automated calibration and verification
  - Internal statistical quality control
  - External quality control (proficiency testing)
  - Remedial action (to correct errors)